

Understanding Pre-Quantitative Risk in Projects

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Abstract

Standard approaches to risk management in projects depend on the ability of teams to identify risks and quantify the probabilities and consequences of these risks (e.g., the 5 x 5 risk matrix). However, long before quantification does – or even can – occur, and long after, teams make decisions based on their pre-quantitative understanding of risk. These decisions can have long-lasting impacts on the project. While significant research has looked at the process of how to quantify risk, our understanding of how teams conceive of and manage pre-quantitative risk is lacking. This paper introduces the concept of pre-quantitative risk and discusses the implications of addressing pre-quantitative risk in projects.

Introduction

As projects move toward developing increasingly complex, technologically advanced works and attempt to layer additional goals, project teams must deal with ever increasing levels of risk. The US National Aeronautics and Space Administration (NASA) routinely pushes at the boundaries of technology, and in doing so has experienced both phenomenal success (e.g., Mars Pathfinder, Hubble Space Telescope) and catastrophic failures such as the Challenger and Columbia disasters. Two independent US government reports published in February 2010 attribute cost and schedule overruns in NASA space missions in part to mishandling risk (Barley, Gilbert & Newhouse, 2010; GAO, 2010). In-depth inquiries into past failures (CAIB, 2003; Rogers, 1986) identify socio-technical issues that contributed to an erroneous evaluation of risk. The many tools and techniques for managing risk in NASA projects are not sufficient because a large number of projects overrun, don't meet schedule, don't perform as expected, suffer from unexpected consequences and in extreme cases, result in catastrophic failures. The problems are not just technical, but rooted in the social structure of the decision-making and design groups (CAIB, 2003; Rogers, 1986).

To improve our ability to address risk effectively therefore requires a better understanding of it at the conceptual level, and particularly the social constructions of risk that underlie technical decisions. This paper presents the results from a study of an in situ project team working on a high-risk project over a seven-month period (see Cooper, 2008 for a detailed description of the analysis techniques). Transcripts from team meetings were analyzed to identify how team members discussed risk: how they conceptualized risk, and how these conceptualizations influenced

team processes. From these analyses, a concept of risk emerged that was much richer than just “negative outcome x probability” that forms the basis for standard risk assessments. The following sections describe this new concept, *pre-quantitative risk*, and discuss the implications for projects in addressing this new conceptualization of risk.

Pre-Quantitative Risk

The most basic definition of risk is from models of economic utility, in which risk is the combination of an outcome (assigned a utility value) and the probability that this outcome will occur (Clemen, 1996). Although risk can be viewed from multiple perspectives (i.e., domains such as public health, safety, finance, engineering), it is perceived relative to some party’s interests; it is not an innate environmental factor that can be studied in isolation or out of context. Human perception of risk can be influenced by emotional (McDaniels, 1998), cognitive (Roberts & Rousseau, 1989), and attitudinal (Waller, Gupta, & Giambatista, 2004) factors. Common to all domains is a general assumption that risk can be managed, and that actions taken by individuals or groups can change risk (Cooper, 2011).

Pre-quantitative risk refers to risks that have not (yet) been quantified. The components of pre-quantitative risk, shown in Figure 1, include a negative outcome and likelihood of occurrence, but also include complex models of interactions among negative outcomes and system elements, and both competing and complementary goals. Team members intrinsically incorporated their ability to influence outcomes or likelihoods into their assessments of pre-quantitative risk. Finally, uncertainty existed on all dimensions (outcomes, likelihoods, interactions, goals, ability to influence). Team members distinguished between an amount of risk (e.g., high or low) and the acceptability of that risk (too risky, not risky enough, acceptable risk). These concepts permeated team discussions, even those where risk was not explicitly addressed.

Negative Outcome and Likelihood

The core of pre-quantitative risk consists of a negative outcome coupled with the likelihood that outcome will occur. In discussion, team members used a rich and varied vocabulary to

Figure 1. Pre-Quantitative Model of Risk

Table 1: Examples of Risk-Related Language

Aspect	Sample Vocabulary
Negative Outcome	Concern, damage, danger, failure, threat
Risky	Aggressive, difficult, tricky, unrealistic
Uncertainty	Doubt, maybe, possibility, somehow, unknown
Likely	Likely, probably, pretty sure, confident
Reduce Uncertainty	Make certain, be sure, need to know
Perceptions (conversational uncertainty cues)	Believe, feel, seem, think
Not a Risk/Not Risky	Acceptable, comfortable, simple, not a problem
Certain	Absolutely, definitely, zero variance
Opportunity (Positive Outcome)	Advantage, nirvana, perfect, success

communicate these concepts, as shown in Table 1. While teams often identified specific instances of risk, general references to negative outcomes, uncertainty and opportunities were far more prevalent throughout the life of the project.

Based on thousands of instances or risk-related vocabulary use, the normalized frequencies of occurrence for the team meetings are shown in Figure 2, which leads to three key observations: First, the classical components of risk permeate team discussions; second, language related to uncertainty dominates negative outcomes, and both dominate opportunities; and third, the use of risk-related language remains fairly constant (e.g., rather than decreasing) over the lifetime of the project.

Goals & Design

The team had multiple goals they were trying to accomplish. These include goals for the immediate project (which was to propose a concept for a Mars mission to NASA for a competitive selection), as well as the mission that would result should the proposal be accepted (scientific measurements of the polar ice cap of Mars as a probe melted its way

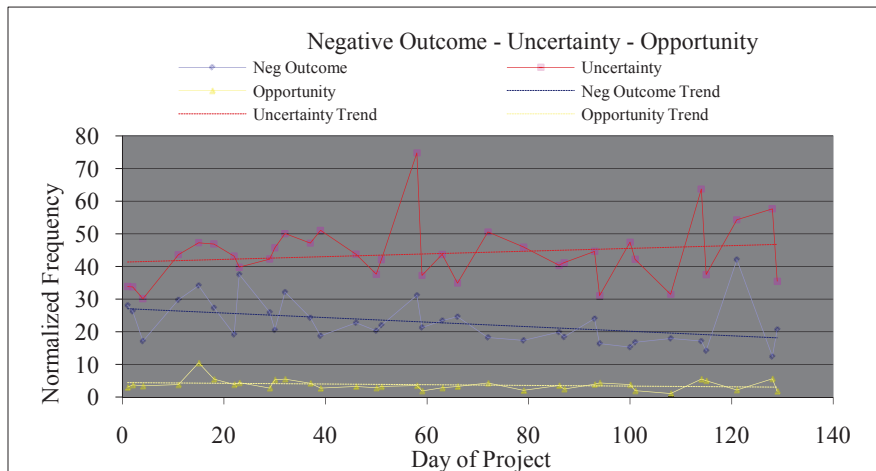


Figure 2. Frequency of Risk-Related Language Use in Team Meetings over Time

through 10's – 100's of meters). The team created a design that could perform this mission

which evolved over the course of the project. The design consisted of spacecraft, lander, probe, and science instrument elements.

Interactions

The negative outcomes, likelihoods, goals and design had significant interactions between and among them. For example, high level goals were both interdependent (e.g., the mission first had to be *selected by NASA* before it could *successfully operate on/beneath the surface of Mars*), and interacted in different ways with design choices (e.g., additional features that improved the likelihood of being able to successfully operate on Mars increased cost in a way that decreased the likelihood of being selected). The team routinely verbalized these interactions during team meetings, where discussion of one topic lead to another, then another as the team essentially used their discussion to verbally simulate complex interaction effects.

Ability to Influence

Team perceptions of risk incorporated members' assessment of their ability to influence the above factors. Team members incorporated reasoning about how they could decrease the likelihood of a negative outcome, address detailed design issues, decouple system elements to reduce interactions, and adjust the design to make tradeoffs between risks relative to different goals. The perceived ability to influence these different factors resulted in a lower assessment of risk relative to those elements, e.g., "My feeling is that this is a solvable problem, if and when we do discover that it is a problem." The ability to influence manifested in multiple forms such as, bringing on an expert in solving a certain type of problem, having multiple design approaches for implementing a feature – with the feeling that at least one of them would work, an assessment that particular resources would be available and that the team member would be able to get them (e.g., test chambers).

Uncertainty

From the language analysis, uncertainty dominated other aspects of risk, in part because there are elements of uncertainty associated with each of the other elements of pre-quantitative risk. Team members regularly referred to uncertainty with respect to what negative outcomes could occur, uncertainty in assessing probabilities or likelihoods for events, uncertainty in the interactions between system design elements, and uncertainty in environmental conditions. Beyond that, however, the team focused on a special type of uncertainty: unknowns, e.g., "*It's a very complex device. It's going to be an unknown environment.*" While team members displayed an acceptance of known unknowns and uncertainties, primarily associated with an ability to influence these uncertainties (through, for example, testing, analysis, searching through research results, bringing someone on to the team with experience in a given area), they perceived "unknown unknowns" as much riskier, e.g., "... *but what about all these things we don't know about because we've never done this before?*"

Judgment

Team members differentiated between the amount of risk (e.g., high, low) and the acceptability of that amount of risk (e.g., too risky, not risky enough). The pre-quantitative conceptualization of risk incorporated judgments assessing the acceptability of aggregated relative levels of risk. Team members continually made judgments whether a proposed approach resulted in more

or less risk, without actually quantifying either option. Risks were aggregated not mathematically, but instead by qualitative assessment relative to a perceived target. Team member perceptions of risk were highest when they were least able to impact risk, i.e., when there was high uncertainty (e.g., unknown unknowns) or when many potential risks were linked together.

Model Summary

The structural elements of pre-quantitative risk, as shown in Figure 1, were evident throughout the entire project. At the heart of the conceptualization of risk were negative outcomes and their likelihoods. These traditional elements of quantitative risk were not explicitly quantified, but were influenced by interactions between goals and among system elements. Layered on top of this was the team's perceived ability to influence the preceding items. And further layered on top of all that was uncertainty in many different forms. Finally, all these factors contributed to team judgments regarding the acceptability of risk. These judgments then influenced the team's actions and contributed to an evolving understanding of risk for this project.

Implications of Pre-Quantitative Risk for Projects

The team members in this study operated primarily with pre-quantitative conceptualizations of risk throughout the study period. Out of hundreds of instances of addressing risk, only a handful involved actually quantifying some aspect of risk. In the vast majority of decisions and actions taken by the team, relative assessments of risk (riskier, less risky) and judgments about the acceptability of risk, guided team processes. Table 2 compares traditional quantitative conceptualizations of risk with pre-quantitative.

This study indicates that project teams may operate for lengthy periods of time based on pre-quantitative assessments of risk. And further, that during these times, teams may make decisions that significantly impact the rest of the project without feeling the need to quantify risk. For this team, and by extension other possible teams working under similar degrees of risk and uncertainty, a pre-quantitative assessment of risk was sufficient to support team processes.

The implications of this work for research and practice are significant. First, this research challenges the validity of the standard 5x5 risk matrix. The 2-factor quantification of risk based on probability and consequence are derived from a much richer representation, and must therefore require team members to combine other factors to come up with a single composite measure for probability. In doing so, they aggregate multiple different types of uncertainty, truncate the effects of goal, design, and outcome interactions, and embed assumptions regarding the team's ability to influence goals, interactions, outcomes and likelihoods. Given the wide variety of factors that get reduced into the 2-factor assessment, it is highly likely that the numbers themselves are suspect, mean different things to different team members, and may not accurately represent the team's concerns.

This research therefore suggests that the squares in the 5x5 risk matrix may be more effectively replaced with bands associated with the matrix's red-yellow-green color coding. These bands can represent the team's assessment of overall riskiness in steps progressing from acceptable to too-risky. Further, the dynamic nature of risk can be captured in a meaningful way in terms of how vulnerable a particular risk is to changing to a different band. In essence, teams could record their simple assessment of risk rather than their attempts to select a combination of numbers in a way that produces the desired assessment. By simplifying the overall representation, teams and their organizations can then focus on the most critical aspects of those risks.

Table 2. Comparison of Quantitative and Pre-Quantitative Conceptualizations of Risk

Element	Quantitative	Pre-Quantitative
Outcomes	Specific negative outcomes, typically measured as cost. May also represent positive risk, but not commonly used. e.g., tornado damages building, cost \$2.1 million	Either specific outcomes or general outcomes such as “concern” or “issue.” Outcomes are primarily negative, but may also be positive (opportunities) e.g., worried that the power supply may fail
Uncertainty	Multiple individual sources and types of uncertainty condensed into a single numerical probability, e.g. 0.56	Multiple individual sources and types of uncertainty aggregated to provide qualitative assessments of probability in the form of likelihoods, e.g., “could happen” or unknowns, e.g., “I just don’t know”
Utility	Arithmetic function of outcome value and uncertainty e.g., \$2.1 million x 0.63	Qualitative assessment relative to yardsticks for cost (risk) and science value (opportunity) e.g., “that’s a big increase in cost for not much gain in science”
Aggregating risks	Arithmetic combination of individual utilities, possibly weighted e.g., $U(a) + U(b)$	Qualitative judgment based on “stacks” of risk and “links” indicating interactions, e.g., five stacked contributors to power system risk, linked to four other parts of the project
Judgment	Based on numerical values e.g., $EU(a) > EU(b)$	Based on qualitative assessment relative to thresholds and balancing overall risk, e.g., the extra science value isn’t worth the risk
Influencing factors	Risk factors and other characteristics of the project or product that indicate higher risk by their mere presence e.g., increase probability of failure to 0.63 due to large number of interactions	<ul style="list-style-type: none"> • Ability to influence • Interactions among goals and risks e.g., “we could ask the engineer to develop a back-up supply”

The 5x5 risk matrix is one of many risk management tools used by projects. Even projects that are mandated to use current risk management tools, however, experience significant problems. This research suggests that one possible reason is the mismatch between how tools represent risk and how team members think about it. The previous discussion suggests one way in which a risk management tool can be modified to make it more user-natural. Areas ripe for both future research and practice are creating new and modifying existing tools to leverage the more natural pre-quantitative model of risk.

This research does *not* suggest that projects should abandon *all* efforts to quantify risk. Instead, it suggests that quantification may be mis-used and counter-productive when assessments of risk are based on *judgments*. When assessments of risk can be based solely on measurable, physical characteristics, then it is appropriate to use quantitative techniques such as probabilistic risk assessments and reliability analyses. Further, the results of these quantitative analyses can become important components of larger, pre-quantitative assessments because they have the potential to significantly reduce different types of uncertainty. Monte Carlo simulations, for example, can reduce uncertainty about probability distributions while failure modes and effects analysis can reduce uncertainty about low level system interactions.

Second, this research identifies a pressing need to better understand how teams actually conceive of and manage risk, rather than how they “should” based on prescriptive, quantitative approaches. The primary motivation for those few times that the team worked to quantify risk was to justify actions the team wanted to take that they felt would be perceived as questionable. In these cases, quantification was used for rationalizing decisions the team had already made. Further, this research suggests that, in the absence of other measures, teams use *cost* as a yardstick for risk, possibly confounding the basis of estimate for cost with implicit assumptions regarding risk. Given the high uncertainty facing NASA (and other) type projects, and the documented difficulties in meeting cost commitments, it is critical to understand the interaction effects between risk and cost used as a measure of risk, and how these effect budgeting processes.

Third, the perception and conceptualization of risk depended on the individuals who made up the team. In some cases, the team recognized a shortfall in experience or capabilities and brought in an expert to help. But in general, the team relied on the capabilities of its members. Team composition, therefore, was a critical factor in the identification of risk. This research, therefore, lends additional credence to the value of diversity, by identifying a new dimension – risk experience diversity. When forming teams, management should consider the *diversity of project experiences*, and actively seek out members who have been exposed to different projects and different risks.

Conclusion

This paper develops the *pre-quantitative risk* construct based on a detailed analysis of team meeting transcripts. It identifies each of the elements that compose pre-quantitative risk and offers a comparison to more classical conceptualizations of risk. Finally, it discusses practical implications of this new conceptualization of risk for projects.

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Biography

Dr. Lynne Cooper has just assumed leadership of the Proposal Center at NASA’s JPL, California Institute of Technology. She received her doctorate in Industrial and Systems Engineering from the University of Southern California. As a practitioner-researcher, she implements and studies systems to support knowledge sharing, innovation, and risk characterization, and has supported multiple Mars missions. She has published research in *Management Science*, the *Journal of Engineering and Technology Management*, and the *International Journal of Knowledge Management*. She reviews for multiple journals, serves as a track co-chair for HICSS and IEEE Technology Management Conference, and is a member of the editorial board for IJKM. She is also a member of the industry faculty for USC’s Daniel J. Epstein Department of Industrial and Systems Engineering.